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ABSTRACT

A 3-year project was designed to increase students' abilities to perform competently as professional engineers. The project sought to infuse into existing courses concern for, practice with, and development of three competencies critical to professional success: problem-solving, communication, and value clarification. Eight elementary and advanced courses, representing about a sixth of a student's total courses were modified over the 3-year period and were taught to one or more of three successive classes of students recruited for the project. This booklet reports highlights of the experiences in modifying and teaching the competence-oriented courses. Included are discussions of project goals, course modifications, and evaluation of results and impacts. Course modifications are discussed under the following heading: focus on professional practices; study guides and assessment manuals; students working as teams; presentations by students to students; videotaping; variety of assignments and use of simulated real-life situations; and assignment periods. Among the evaluation results/impacts reported are those indicating that: (1) the communication competency was the most successful of the three competencies introduced, (2) the teaching of competence did not decrease subject matter emphasis in course work, and (3) the modification of only a small portion of courses can have a major impact on student competence development. (JN)

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at The Cooper Union
School of Engineering

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Professional Competence Development at the Cooper Union School of Engineering

Project Highlights

School of Engineering
The Cooper Union for the Advancement of Science and Art
41 Cooper Square
New York, NY 10003

December 1982

The Cooper Union for the Advancement of Science and Art, established in 1859, is a private, tuition-free institution of higher learning. Peter Cooper's legacy supports the School of Art, the School of Architecture, and the School of Engineering, all of which grant degrees; the Faculty of Liberal Arts and Sciences, and the Division of Adult Education, which administers the historic Cooper Union Forum. The Cooper Union is located at Cooper Square, New York, NY 10003.

This report prepared in collaboration with Educational Facilities Laboratories, a division of the Academy for Educational Development, New York, NY. Ellen Bussard is the primary author.

Introduction

The Cooper Union School of Engineering recently completed a three-year project, funded by the National Science Foundation, to increase students' abilities to perform competently as professional engineers.

The project sought to infuse into existing courses concern for, practice with, and development of three competences critical to professional success: problem-solving, communication, and value clarification. Eight elementary and advanced courses, representing about a sixth of a student's total courses at The Cooper Union, were modified over the three-year period and were taught to one or more of three successive classes of students recruited for the project.

This booklet reports highlights of the Cooper Union experience in modifying and teaching competence-oriented courses. A second publication, "Project Report," describes the project and lessons learned in more detail. A third report compiles specific course materials generated as part of the project, and is intended to be useful to faculty in other engineering schools who may also be concerned that engineering education lead to broad professional development that goes beyond mere technical competence.

Our goal is not to hold up our experience as a model–indeed we had our frustrations–but to share with colleagues the lessons learned in an extended experiment that is new and vitally important to professional engineering education.

Similar efforts are underway in other fields of professional study, most notably in medicine, where medical schools are struggling with how to teach students skills for dealing with people as well as patients and diseases, and where values are critical when making therapy choices and life and death decisions.

Background

The professional competence development project is one of three areas of innovation at The Cooper Union that resulted from a comprehensive review of the school's curriculum, carried out in 1976–77 and prompted by concern for increasing the breadth and applicability of engineering education.* Programs were initiated, also, to increase the integration of the humanities and engineering in the undergraduate curriculum and to develop experiential learning situations through professional internships.

Concern about professional competences stems from the fact that engineering graduates are likely to assume a number of different roles in their professional careers–managers and members of problem-solving teams, designers and inventors, researchers, and academics. Ability to move comfortably among these roles is a valuable asset.

Two principles guided development of the Cooper Union professional competence project. First, competence development would be integrated within the existing course curriculum without changing the number of courses and credits, or the academic course content. Competence development would not be added as an extra or isolated subject of study, nor would the technical and scientific curriculum be reduced to accomodate competence training. Second, development of professional competences would take place throughout the undergraduate period, with increasing accomplishment expected during the four years.

The Project

The project concentrated on developing three competences among students: problem-solving, communication, and value clarification. Problem-solving was defined as the ability to analyze problems, to synthesize data, to relate problems to a wider context, and to develop and implement solutions. Communication was defined as the ability to listen to others; to receive and convey information through writing, drawing, and speaking; and to keep an audience in mind while communicating. The third competence, value clarification, included the ability to recognize the values held by oneself and others and to understand how they influence definition and solution of problems. Mastery of these three competences would greatly enhance the professional skill of Cooper Union graduates, and would complement their technical and scientific education.

The approach taken was for a small group of faculty, seven out of thirty-five members of the engineering school, to modify eight courses which they regularly taught to include practice in the three competences. The eight courses included both elementary and advanced courses, given to freshmen through seniors. They were: mechanics, introductory physics lab, analytic geometry and calculus, introduction to politics, linear systems, engineering design and problem-solving, environmental fundamentals, and basic humanities. Three successive groups of twenty-five first-year students were recruited on the basis of interest to participate in the project. During their four years, students earned 11 to 18 credits, representing 9–13% of total credits, in competence-based courses.

*This study was called SHAPE, an acronym for Synthesis of a Holistic Approach to Professional Education, and was supported by the Mellon Foundation. A complete report is available from The Cooper Union: "A Plan for a Holisitic Approach to Professional Education–A Report to The Andrew W. Mellon Foundation," October 1977, The Cooper Union.

Course Modifications

Although all participating faculty members attended a series of workshops on competence development, received a core set of materials, and worked from the same broad theoretical outline, specific course modifications were made independently by each professor. Given the diversity of courses and professors, a variety of specific course modifications could have been expected and were introduced. However, many modifications introduced were common and can be grouped under a few headings*:

Focus on professional practices

Faculty reported that they broadened the focus of their courses to include the professional practice of engineering. They stressed the application and tie-ins of course subject matter, projects, and exercises to professional situations. For example, physics laboratory reports were modified to more closely resemble the type of experimental documentation required in professional practice. The importance of the problem had to be explained; methods for studying the problem had to be discussed and the approach used had to be justified; drawings of experimental apparatus were required; data gathering and analysis sheets had to be designed; and the findings had to be clearly described and analyzed for theoretical and practical significance. Bringing awareness of competence development to the forefront, alongside subject content, increased the intensity of each course.

Study guides and assessment manuals

For the first time, many participating faculty members shared with students detailed course outlines, weekly assignment plans, and lecture notes. Some presented all these materials at the beginning of the course, while others distributed the materials in short modules throughout the semester.

Students working as teams

Many courses were modified to allow and/or require students to work together in small and large groups. Group work included discussion and problem-solving in design and math, joint physics lab reports by lab partners, out-of-class research and preparation of written reports and oral presentations, in-class oral presentations and seminars, and videotaped presentations. Students gained practice in leading teams and being team members, in organizing an approach to problem-solving and delegating responsibility, and in pulling the pieces together into a coherent whole. This approach was used in a semester class project on designing a self-sufficient small community, and in a two-week assignment preparing a videotaped roundtable discussion on the role of the constitution in maintaining existing power structures and/or preserving democracy. These were marked departures from traditional individual assignments.

Presentations by students to students

Students very often made presentations before each other, as individuals or teams, and critiqued each others' performances. Presentations ranged from homework problems at the blackboard to formal seminars and roundtable discussions. In the environmental science course, one quarter of class meeting hours were devoted to student lectures on technical issues they had researched in depth; gasohol conversion, pesticides, sewage treatment and methane production, and catalytic converters, for example. In the physics lab, 6-person teams developed and gave 1½ hour presentations on one of the topics covered in a lab exercise. Previously most interactions had been between students and professors–either by professors leading the classes or through written homework assignments.

*For a more complete description of this and other aspects of the project, see "Professional Competence Development: The Cooper Union Experience."

Videotaping

Most of the courses introduced and required videotaping as a means for enhancing and assessing personal presentation skills. Students used the Cooper Union A/V laboratory to rehearse and prepare for class presentations and to produce finished tapes, which were themselves turned in as assignments. In addition, a technician was available to come into the classroom and tape a "live" class presentation so that students could later review their own presentations. None of the courses had used videotape before.

Variety of assignments and use of simulated real life situations

Readings beyond the basic course texts were introduced, and new types of assignments–essays, reports, and oral presentations–were given. More depth was required of many class exercises, such as stating assumptions and constraints to solving a problem and justifying the solution approach used, as well as providing the numerical answer. A major class assignment based on a real life situation–preparing a policy report on recommending whether New York City taxis should be required to convert to diesel fuel–was used as the focus of the environmental fundamentals course. In the calculus course, 5-person student teams applied abstract calculus to practical problems and real phenomena in engineering, medicine and physics, and prepared a videotaped presentation. In many cases, with small modifications, an academic exercise was changed to a simulated professional problem, and students were required to deal with social, economic, and political as well as technical issues.

Assignment periods

Class assignments of several days to several weeks, and occasionally an entire semester, were introduced in addition to or instead of daily assignments. These more complex assignments more closely resemble professional situations.

Evaluation of Results and Impacts

Project evaluation was carried out through student surveys during and at the completion of the project, and through interviews with participating and nonparticipating faculty members. The student survey administered at the end of the project provides hints at the nature of long term impacts on students who had taken the full sequence of courses offered and/or who had sampled the world of professional practice through summer employment. It is still too early to have reports from students after graduation.

To see if the competence project would result in measurable achievement among students, a competence assessment test developed by The American College Testing Program was administered the first year to incoming students who would participate in the project. The test will be adminstered again to the same students in the 1982–83 school year.

The following section highlights the key findings of the Cooper Union project, based on the interview and survey data:

The communication competence was by far the most successful of the three competences introduced.

All indicators clearly suggest that the communication competence was most sought after by students, most easily understood by faculty and students, most emphasized, and had the greatest effect.

Nearly half of the students interviewed at the end of the project singled out the promise of improving communication skills as the most important factor in enrolling in the competence development project. They also rated the project courses as very effective, and considerably more effective than other courses, in actually improving these skills. Improvements in oral communication, which received the greatest emphasis in course modification, were felt to be dramatic. Many students singled out the videotaping as a significant learning tool. Oral class presentations also represented the clearest departure from traditional course structure.

Project faculty concurred in emphasizing the importance and success of enhancing communication skills.

Nonproject faculty reported feeling that students in the project were better able to present themselves and participate in class discussions. This was the only point on which nonparticipating faculty agreed that the competence courses made a difference.

Despite the lack of any formal school-wide discussion or analysis of the competence development project, many faculty members are now introducing oral class assignments, further suggesting that oral communication competence has achieved broad recognition.

Finally, an important benefit of the communication skills practice identified by students–and not anticipated at the beginning of the project–was a substantial increase in self-confidence. Typical of answers to post-project survey questions asking about the impact of the project were these:

"I feel much more confident speaking in public."

"I feel I would have an advantage presenting a solution to a group of clients."

"I learned I can make people listen to me."

"My ability to communicate my thoughts and ideas to other people has increased my confidence. Communication skills enhance engineering knowledge."

"The courses made me more outgoing and confident."

Experience with skills of problem-solving and value clarification was more problematic.

Although participating faculty members felt they were successful in adding more depth and breadth to the concept of problem-solving in their courses, student perceptions were more mixed. In the summary survey students rated problem-solving fairly high in all courses they took at The Cooper Union. Nonparticipating faculty members did not report a noticeable difference between students who were and were not in the project. We are not sure how to evaluate this response–perhaps we are more successful in teaching problem-solving than we thought, or perhaps the differences introduced were too subtle to stand out clearly.

Faculty and students had difficulty applying the value clarification competence to most courses. They reported some bafflement and tended to de-emphasize or abandon it over the three-year period. Although students rated value clarification somewhat higher in competence-oriented courses than in other courses, the ratings were rather low.

The post-project survey, however, revealed that a number of students were finding the value clarification emphasis valuable in personal and academic or professional life. Quite a few students asked that there be more emphasis on value clarification, while suggesting that it be better integrated into courses.

Students did not suffer in academic achievement

A concern of many nonparticipating faculty members had been that subject matter course content might suffer in courses modified to emphasize professional competences. Although the lack of standardized academic achievement tests at The Cooper Union precludes any objective measure, all indications are that this fear was groundless.

Participating students and faculty both felt students learned as much in competence courses as in their other courses. Many faculty teaching competence-oriented courses felt that their students in fact learned more, and more deeply, than students they had taught before. Further, they felt that the course modifications introduced gave them better insight into the students' grasp of subject matter, and therefore allowed them to better correct areas of weakness.

Nonparticipating faculty who teach follow-up courses have not reported any inadequate preparation by participating students.

Student reactions to the project were strong–some very positive and some very negative.

After an initial period of groping to understand the nature of course changes and expectations, students appeared either to embrace with enthusiasm or to reject the idea of competence development. Faculty members who had students at both ends of the spectrum were hard pressed to make generalizations about the two groups or to find distinguishing characteristics.

Students who were enthusiastic enjoyed the extra dimension of challenge and accomplishment, and seemed to gain immediate rewards. Students who reacted negatively to the project seemed overwhelmed by being criticized on all fronts–they felt it was unfair to be judged on presentation methods as well as answers. It is safe to assume that they did not get any immediate sense of accomplishment.

One possible interpretation is that the competence emphasis was entirely new and overwhelming to some students and that they may have needed a more gentle introduction. The project may also have been quite different from their expectations. Certainly it would seem wise to keep open an option for students to transfer out of a competence-oriented program as long as the program is voluntary.

Progress in competence development is visible, but difficult to gauge on a specific scale.

The Cooper Union project initially established a matrix of three distinct proficiency levels for each competence.* The intent was to provide a scale for assessing progress in each competence and for planning course modifications. In practice, this scale proved cumbersome at best, and was abandoned during the project.

Faculty felt the concept of progressive levels of mastery was important for course planning, but requires much closer coordination in course development than was practiced at The Cooper Union. The scale, when introduced to students, was more confusing than helpful, and was not effectively used in giving students feedback. Faculty felt they could adequately help students to make progress without resorting to this scale, and suggested that any future use of the scale be reserved for the purpose of course development.

Competence-oriented courses required significantly more work from students and faculty.

Many course modifications required more out-of-class preparation time from students than the class assignments they replaced. Writing essays and reports, making videotapes, and preparing to give seminars or to lead roundtable discussions all took considerable student time. They also required more effort of faculty, particularly since faculty were committed to reviewing assignments in terms of presentation techniques as well as academic content.

Faculty members, who had been given a reduced teaching load during the semester when they developed course modifications, also would have preferred a reduced load during the first semester of actual teaching. Further, most felt that they would not want to teach more than one course at a time with the competence emphasis, because of the extra workload.

Students, too, felt that the extra work required of taking one or two, out of five, courses with the competence orientation was the limit that could be sustained.

*See *Professional Competence Development at the Cooper Union School of Engineering: Project Report*.

Modification of only a small portion of courses can have a major impact on student competence development.

The communication competence practice, in particular, had significant impact on students, even though only about 9–13% of total student credits were taken in competence-oriented courses. This is an important observation, in view of the extra burden of work required in these courses. One implication of this assessment might be that in any school-wide adoption of professional competence development only a small fraction of all courses needs to be greatly modified, while others could be modified slightly to reinforce the skills learned.

If this conclusion holds, it promises schools flexibility in selecting courses most adaptable to the competence approach and in permitting self-selection of faculty, without sacrificing impact. It also suggests that significant improvement in students' professional development can be obtained without major overhaul of the curriculum.

If only a few courses are to be modified, it is probably important that there be greater coordination among those courses than was the case in the Cooper Union project. In keeping with long-standing school tradition, each Cooper Union faculty devised course modifications independently, for the most part. The small degree of coordination among participating faculty resulted in minimal progression of competence development to advanced levels, and loss of opportunities for exercises in one class to build on or complement those in another class.

Finally, the Cooper Union experience suggests any school-wide approach to professional competence development in which relatively few courses are significantly changed would also need understanding and support from the entire faculty. Faculty support is needed so that other courses could reinforce skills and the importance of competence development. At The Cooper Union this project was carried out in some degree of isolation from nonparticipating faculty, resulting in confusion and tension. There was confusion about whether the project was a special honors program and whether it somehow represented an "attack" on faculty who did not participate. This lead to defensiveness among both participating and nonparticipating faculty members. Unless the importance of professional competence is recognized throughout the school, competence-oriented courses stand in danger of being seen as idiosyncracies, rather than as an integral part of the educational experience.

In Sum

The professional competence development project at The Cooper Union is having a pervasive impact on the school. The faculty has developed heightened awareness of the importance of broad professional education. Many courses, including the most traditional, are being reorganized with a project orientation and with new emphasis on comprehensive problem-solving skills. Faculty members who did not participate in the project are introducing more oral and written communications practice in their classes, and the school's curriculum committee is investigating methods for systematically developing communication competence in all courses.